International Journal of Infectious Diseases 17 (2013) e299–e303

Contents lists available at SciVerse ScienceDirect

International Journal of Infectious Diseases

journal homepage: www.elsevier.com/locate/ijid

The role of imaging of the urinary tract in patients with urosepsis

Signe M. Sørensen, Henrik C. Schønheyder, Henrik Nielsen *

Departments of Infectious Diseases and Clinical Microbiology, Aalborg Hospital, Aarhus University Hospital, DK9000 Aalborg, Denmark

ARTICLE INFO

Article history:
Received 28 April 2012
Received in revised form 26 October 2012
Accepted 2 November 2012

Corresponding Editor: Andy Hoepelman, Utrecht, The Netherlands

Keywords:
Urosepsis
Bacteremia
Imaging
Ultrasonography
CT scan

SUMMARY

Objectives: The aim of this study was to provide recommendations for imaging of patients with urosepsis in order to detect urological complications that need intervention, as well as conditions that predispose to renal infection.
Methods: We reviewed the medical records of 221 adults admitted to a Danish university hospital from 2005 to 2009 with community-acquired bacteremia with a urinary tract focus.
Results: Major abnormalities were found in 37 out of 115 (32%) patients. The two most common major abnormalities were hydronephrosis (17%) and urolithiasis (6%). Predictors of a major abnormality were diabetes with complications and any of the following: renal disease, pre-existing urological abnormality, or nephrolithiasis. Gender, age, blood pressure, fever, malignant disease, liver disease, neurological disease, prostatic disease, chronic indwelling urinary catheter, C-reactive protein, and white blood cell count did not show a statistically significant association with major abnormalities.
Conclusions: A large proportion of patients scanned in this study had a clinically important radiological finding. A positive history of diabetes with complications, renal disease, urolithiasis, or a structural urological abnormality in uroseptic patients may be particularly helpful in identifying those for whom an imaging procedure should be performed.

1. Introduction

Urinary tract infection (UTI) is a heterogeneous condition ranging from mild cystitis, easy to treat with oral antibiotics, to life-threatening bacteremia with shock and multiple organ failure. The term urosepsis signifies bacteremia with a urinary tract focus. Patients with urosepsis and a suspected upper UTI need special attention because these patients may require radiological evaluation in order to discover urological complications, such as renal abscess or pyonephrosis, or conditions that predispose to renal infection, such as structural malformations. Radiological findings may lead to treatment adjustment or urgent interventions to drain the infectious focus or prevent permanent loss of renal function. Previous reports concerning radiological evaluation of the urinary tract during acute infection have primarily focused on the advantages and disadvantages of the different modalities of examination.[1–4] Guidelines have varied over the years, reflecting changes in the accessibility of the different modalities and also different national attitudes towards exposure to ionizing radiation.

Few studies have attempted to create evidence-based guidelines regarding which patients require uroradiological evaluation and the most appropriate time for this during the course of infection. There is consensus that most cases of pyelonephritis in young, otherwise healthy women are uncomplicated and do not need radiological imaging. Some authors suggest radiological evaluation in illness not responding to treatment,[5] other authors advise radiological evaluation in the critically ill and immunocompromised, when the diagnosis is in doubt, or when the clinician suspects complications.[6] Kawashima et al. suggest that imaging be performed in patients with a poor response to antibiotic treatment after 3 days, if the diagnosis is in doubt, in recurrent UTI, and in patients at increased risk of complications (patients with diabetes, AIDS, renal transplant, and the immunocompromised).[7] A prospective observational study reported that only fever for more than 3 days after admission or previous history of urolithiasis were significant factors predicting major abnormalities on ultrasound.[8] Diabetes was also associated with this outcome, although the numbers did not reach statistical significance. Recently, a large multicenter study from The Netherlands by van Nieuwkoop et al.[9] derived and validated a clinical prediction rule for adults with febrile UTI, i.e., a history of urolithiasis, urine pH $\geq$7.0, and renal insufficiency (estimated glomerular filtration rate (GFR) $\leq$40 ml/min/1.73 m^2), giving a negative predictive value of 93% and a positive predictive value of 24% for any clinically significant radiological finding.

The aim of our study was to determine which uroseptic patients would benefit from radiological evaluation because of the likelihood of finding relevant changes such as urologic complications that

* Corresponding author. Tel.: +45 99326525; fax: +45 99326008.
E-mail address: henrik.nielsen@rn.dk (H. Nielsen).

1201-9712/$36.00 – see front matter
http://dx.doi.org/10.1016/j.ijid.2012.11.032

need intervention and conditions that predispose to renal infection. Initially, we investigated the current use of acute radiological examination of the urinary tract in patients with urosepsis at our institution. We then estimated the prevalence of abnormal findings by ultrasound and/or computed tomography (CT) and sought to identify clinical parameters that could predict abnormal findings.

2. Materials and methods

2.1. Establishment of the patient cohort

Patients admitted to a medical department at Aalborg Hospital with first-time bacteremia during the period 2005 to 2009 were identified in the North Jutland Bacteremia Research Database. The settings and criteria for assessment of bacteremia have been published previously.[10] Inclusion criteria were blood cultures performed within 48 h after admission, confirmed community-acquired bacteremia with a urinary tract focus, and age >17 years. Community-acquired bacteremia was defined as an episode of bacteremia present or incubating at admission to the hospital. Urinary tract focus was defined in the Bacteremia Research Database during admission by a combination of clinical information from the treating clinician, ruling out other possible infectious foci, and the specific microbiological findings. All cases were later reevaluated by a clinical microbiologist in order to ensure the quality of the registration. Cases with an uncertain infectious focus were classified as 'unknown focus'.[11] Patients with clinical signs of UTI but a positive blood culture indicating another focus were excluded. Patients with previous episodes of bacteremia were also excluded, with exception of one patient with erysipelas and *Streptococcus pyogenes* bacteremia 4 months previously.

Electronic admission files, laboratory data, and written radiologic reports were reviewed. The patient's previous admission files from hospitals outside of the North Jutland Region were not accessible. Comorbidities known at the time of admission were registered. The category 'renal disease' included patients for whom renal disease was mentioned in the current or previous admission file, as well as patients who had previously had an elevated level of plasma creatinine. Only type 2 diabetic patients requiring medical treatment were registered as diabetics. Diabetic patients with known micro- or macrovascular manifestations, including diabetic retinopathy, renal affection, neuropathy, myocardial infarction, cerebral thrombosis, and claudication, were classified as 'diabetes with complications'. The category 'neurological disease' included only patients with a known affected urinary bladder. 'Prostatic disease' was considered when the patient was undergoing or had undergone medical or surgical treatment. Five patients died less than 24 h after admission, before the diagnosis of urosepsis as well as a decision regarding radiology had been made.

Medical records were used to determine whether an imaging procedure had been performed. Patients who had undergone diagnostic imaging were compared with patients who had not undergone an imaging procedure to detect differences that may have reflected the clinician's judgment as to whether a scanning procedure was indicated. Patients with major findings were compared to patients with a normal scan or only minor abnormalities to analyze which parameters were associated with the diagnostic outcome of the imaging.

With regard to patients who did not undergo diagnostic imaging during their primary admission with urosepsis, admission files, microbiological data, and radiological examinations were reevaluated after 1 year in order to determine recurrences with or without the performance of ultrasonography or CT scans.

2.2. Assessment of outcomes

Outcomes of abdominal ultrasonography and/or CT scan were classified as 'major abnormalities', 'minor abnormalities', or 'normal'. A major abnormality was defined as a finding that should influence subsequent treatment and included urgent urological complications, non-urgent urological conditions, and suspected malignant tumors. A minor abnormality was a finding considered to be incidental, e.g., renal cysts, small kidneys, and calcifications in the renal parenchyma or signs of acute renal inflammation.

2.3. Statistical analysis

Fisher's exact test, the Chi-square test, and the Wilcoxon test were used for the statistical analysis. A p-value of <0.05 was considered statistically significant. A multivariate analysis of data from 115 patients was performed by logistic regression with inclusion of 'diabetes with complications', 'urological abnormalities', age, and sex as the variables deemed most clinically relevant. The result of scanning was not evaluable for one patient, and this case was excluded from the multivariate analysis. Goodness-of-fit was evaluated using the Hosmer–Lemeshow test (Stata version 9.2; College Station, TX, USA).

2.4. Ethical considerations

This historical cohort study was conducted in accordance with the guidelines of the regional scientific ethics committee for the use of clinical and laboratory data and was approved by the Danish Data Protection Agency (Record No. 2006-41-6176).

3. Results

A total of 221 adult patients with first-time urosepsis were included in the study. The bacterial isolates in blood culture were predominantly *Escherichia coli* (79%), followed by *Klebsiella spp* (8%) and other enterobacteria (7%) (Table 1).

Radiological imaging had been performed in 116 patients (52%) – 74 females and 42 males. The patients who had undergone a scanning procedure were generally younger (median 71 vs. 77 years), had a higher level of C-reactive protein (CRP) (193 vs. 147 mg/l), and a slightly higher level of plasma creatinine (122 vs. 110 μmol/l) on admission. There were no significant differences in the distribution of comorbidities, vital signs, or leukocyte count (Table 2).

Table 1
Bacterial isolates in blood cultures from 221 patients with first-time urosepsis

Finding	Monomicrobial	Polymicrobial
Number of patients	213	8
Gram-negative rods		
Escherichia coli	165	9[a]
Klebsiella spp.	18	-
Other enterobacteria	12	3
Miscellaneous[b]	3	-
Gram-positive cocci		
Enterococcus faecalis	9	2
Streptococcus spp[c]	2	2
Aerococcus urinae	2	1
Miscellaneous[d]	2	1

[a] Three patients had two *Escherichia coli* isolates with different antibiograms.
[b] Pseudomonas aeruginosa, Aeromonas sp, and Prevotella sp in one patient each.
[c] β-Hemolytic streptococci in three patients and *Streptococcus sanguis* in one patient.
[d] Coagulase-negative staphylococci in two patients and *Corynebacterium sp* in one patient.

Table 2
Demographic, clinical, and biochemical characteristics of 221 adult patients with community-acquired bacteremia with a urinary tract focus in relation to whether ultrasonography and/or CT scan was performed

Variable	*N*	Any scan		*p*-Value
		No (*n* = 105), *n* (%)	Yes (*n* = 116), *n* (%)	
Gender				
Female	134	60 (57)	74 (64)	0.23
Male	87	45 (43)	42 (36)	
Age, years, median (IQR)	(221)	77 (64–85)	71 (60–80)	0.002
Type 1 DM	6	2 (-)	4 (-)	-
Type 2 DM	47	22 (21)	25 (22)	0.91
DM with complications	38	20 (19)	18 (16)	0.59
Malignancy – solid	31	15 (14)	16 (14)	0.91
Malignancy – hematological	5	2 (-)	3 (-)	-
Liver disease	7	2 (-)	5 (-)	-
Renal disease	68	33 (31)	35 (30)	0.88
Nephrolithiasis	14	3 (3)	11 (9)	0.05
Urological abnormality[a]	9	3 (3)	6 (5)	0.50
Neurological disease	16	9 (9)	7 (6)	0.61
Prostatic disorder	28	18 (17)	10 (9)	0.07
Permanent urinary catheter	26	16 (15)	10 (9)	0.15
Alcoholism	23	12 (11)	11 (9)	0.67
Body temperature, median (°C)	(216)	38.6 (37.9–39.3)	38.7(37.7–39.5)	0.89
Systolic blood pressure (mmHg)	(217)	122 (107–138)	129 (114–147)	0.07
Diastolic blood pressure (mmHg)	(217)	65 (59–74)	69 (58–80)	0.07
C-reactive protein (mg/l)	(221)	147 (55–208)	193 (81–288)	0.004
Blood leukocytes ($\times 10^9$/l)	(221)	13.9 (10.1–17.4)	14.7 (10.5–19.4)	0.17
Blood neutrophils ($\times 10^9$/l)	(201)	12.2 (8.3–15.8)	13.0 (8.9–16.5)	0.48
Plasma creatinine (μmol/l)	(221)	110 (83–160)	122 (90–200)	0.07

CT, computed tomography; DM, diabetes mellitus; IQR, interquartile range.
[a] The urological abnormalities were chronic hydronephrosis, ureteral stenosis after radiation therapy, Bricker bladder, duplex kidney, graft kidney, JJ-catheter, or nephrostomy catheter.

Major abnormalities were found in 37 of the 115 (32%) patients (Table 3). The most common major abnormalities were hydronephrosis/pyonephrosis (n = 20, 17%) and renal stones (n = 7, 6%). The following biochemical and clinical parameters were statistically significant predictors of a major abnormality: plasma creatinine (p = 0.002), type 2 diabetes (p = 0.03), diabetes with complications (p = 0.004), known renal disease (p = 0.02), and known urological abnormality (p = 0.01), or alternatively, any one of the following: a history of renal disease, urolithiasis, congenital or acquired structural abnormality (combined, p = 0.001). By multivariate analysis adjusted for age and sex, diabetes with complications was an independent predictor of the outcome (odds ratio (OR) 3.8, 95% confidence interval (CI) 1.2–11.4), as well as renal disease, nephrolithiasis, or urological abnormality combined, with an OR of 3.9 (95% CI 1.6–9.3). Other clinical parameters such as blood pressure, fever, malignant disease, liver disease, neurological disease, prostatic disease, chronic indwelling urinary catheter, CRP, and white blood cell count did not show a statistically significant association with the finding of a major abnormality (Table 4). Minor abnormalities were found in 55 of 115 (48%) patients. Renal cysts (n = 21, 18%) and signs of acute pyelonephritis (n = 21, 18%) were the most common findings, followed by renal atrophy (n = 9, 8%). Altogether, 18 patients had both major and minor abnormalities.

A urological intervention occurred in 15 patients. An acute nephrostomy was performed in seven patients. Placement of a JJ-catheter or the replacement of an existing JJ-catheter was done as an acute or subacute procedure in five patients. Three patients underwent other acute interventions such as drainage of infected cysts, drainage of air space, or change of permanent urinary tract catheter. Two patients later underwent nephrectomy because of either emphysematous pyelonephritis or solid tumor. Five patients subsequently underwent stone removal by ureteroscopy or extracorporeal shock wave lithotripsy. As the numbers imply, some patients had more than one procedure performed.

Table 3
Major and minor abnormalities on ultrasonography and/or CT scan in 115 adult patients with community-acquired urosepsis.[a] Some patients had more than one abnormality

Finding	*n* (%)
Major abnormality	
Hydronephrosis/pyonephrosis	20 (17)
Renal stone	7 (6)
Solid tumor	6 (5)
Ureterectasis[b]	4 (3)
Caliectasis[b]	3 (3)
Duplex kidney	3 (3)
Ureter stone	2 (2)
Ureteral stenosis	2 (2)
Infection in polycystic kidney	1 (1)
Emphysematous pyelonephritis	1 (1)
Signs of early renal abscess	1 (1)
Displaced nephrostomy	1 (1)
Minor abnormality	
Signs of acute pyelonephritis (edema, increased differentiation between medulla and cortex)	21 (18)
Renal cyst	21 (18)
Small kidney	9 (8)
Minor calcifications in renal parenchyma	6 (5)
Extrarenal pelvis	5 (4)
Renal scar	5 (4)
Signs of acute cystitis (thickened bladder wall, unclear urine)	4 (3)
Residual urine in the bladder	3 (3)
Enlarged retroperitoneal lymph nodes	2 (2)
Other change not suspected to be tumor	2 (2)
Bladder diverticulum	1 (1)
Horizontal kidney	1 (1)
Angiomyolipoma	1 (1)

CT, computed tomography.
[a] The results were not evaluable in one patient.
[b] Caliectasis and ureterectasis represent a chronic degree of obstruction and were defined by the radiologist upon assessment of the ultrasonography or CT scan in comparison with normal anatomical measures in adult patients.

Table 4
Predictors of major abnormalities on ultrasonography and/or CT scan in adult patients with community-acquired urosepsis

Variable	*N*	Major abnormality		Univariate *p*-value
		No (*n* = 78), *n* (%)	Yes (*n* = 37), *n* (%)	
Sex				
Female	74	50 (64)	24 (65)	1.00
Male	41	28 (36)	13 (35)	
Age, years, median (IQR)	(116)	69 (57–79)	73 (61–80)	0.59
Type 1 DM	4	3 (4)	1 (3)	-
Type 2 DM	25	12 (15)	13 (35)	0.03
DM with complications	18	7 (9)	11 (30)	0.004
Malignancy – solid	16	9 (12)	7 (19)	0.38
Malignancy – hematological	3	1 (1)	2 (5)	-
Liver disease	5	5 (6)	0 (0)	-
Renal disease	34	17 (22)	17 (46)	0.02
Nephrolithiasis	11	5 (6)	6 (16)	0.17
Urological abnormality	6	1 (1)	5 (14)	0.01
Any of the three above	41	19 (24)	21 (57)	0.001
Neurological disease	7	3 (4)	4 (11)	0.21
Prostatic disorder	9	6 (8)	3 (8)	1.00
Permanent urinary catheter	9	4 (5)	5 (14)	0.14
Alcoholism	11	10 (13)	1 (3)	0.10
Body temperature, median (°C)	(113)	38.7 (37.9–39.5)	38.5 (37.4–39.6)	0.89
Systolic blood pressure (mmHg)	(114)	130 (112–150)	129 (117–146)	0.62
Diastolic blood pressure (mmHg)	(114)	70 (60–83)	65 (57–77)	0.25
C-reactive protein (mg/l)	(115)	196 (62–283)	192 (103–298)	0.44
Blood leukocytes ($\times 10^9$/l)	(115)	14.1 (10.1–18.4)	16.5 (11.6–21.4)	0.06
Blood neutrophils ($\times 10^9$/l)	(102)	11.9 (8.4–15.3)	14.6 (9.7–17.5)	0.13
Plasma creatinine (μmol/l)	(115)	107 (79–164)	168 (108–326)	0.001

CT, computed tomography; DM, diabetes mellitus; IQR, interquartile range.

Follow-up of the 105 patients without radiological assessment during the episode of bacteremia revealed that 10 cases had been re-admitted with urosepsis during the following year, and for six of these patients, ultrasonography and/or CT scan of the urinary tract was indicated. Major abnormalities were detected in three patients: one had renal stone, one had suspected minor renal abscesses and dilatation of the calyceal system, and one had dilatation of the ureteropelvic junction. One patient had two episodes of bacteremia with different urinary tract pathogens, and another patient had four episodes of *E. coli* bacteremia. One patient had spondylodiscitis due to the same pathogen that had caused the urosepsis. Four patients without recurrent urosepsis who were scanned due to another indication had major urinary tract abnormalities at 1-year follow-up.

4. Discussion

The routine performance of imaging studies in patients with UTI is reported to be of little value,[4,12] but the clinical characteristics related to a high probability of detecting clinically important imaging abnormalities are not well known. The present study demonstrates a high frequency of major abnormalities found on imaging of the urinary tract in patients with bacteremia with a urinary tract focus, and certainly a somewhat higher prevalence than previous reports on febrile UTIs.[8,9,13] These discrepancies possibly reflect differences in patient characteristics between studies since in our cohort we included only bacteremic cases, which we believe represent a more advanced and severe form of UTI. Furthermore, additional cases with major abnormalities were detected during the 1-year follow-up in patients not examined initially.

We observed a higher risk of major abnormalities in patients with diabetes with complications or a history of renal disease, urolithiasis, congenital, or acquired structural abnormality. Due to anatomical differences, the incidence and clinical characteristics of UTI differ between men and women, but we did not detect any difference in the frequency of major abnormalities on imaging between men and women with urosepsis. Surprisingly, age was not a predictor of radiological abnormalities in the univariate analysis. CRP and leukocyte count were not associated with an increased risk of finding a major abnormality, which is in contrast with an earlier report.[4]

The study by van Nieuwkoop et al.[9] involved 490 patients who had a febrile UTI, but not all were admitted to hospital. Approximately a fifth (95 patients) had bacteremia, like our group of patients. In the derivation cohort, 245 of 346 patients (71%) underwent radiology. This is quite a large fraction considering the moderate severity of infection in this group of patients. In our cohort only about half the patients with urosepsis underwent a radiological examination. It is a pertinent question whether we performed too few scanning procedures, especially in light of the fact that some of our patients had a urinary tract abnormality detected during follow-up. Because of the infrequent registration of urinary pH in our patients, we were not able retrospectively to test whether the Dutch prediction rule[9] could be verified in our cohort of patients.

In the investigation of anatomical abnormalities and obstruction due to urolithiasis, intravenous urography previously played a predominant role [14]. However, the same information on the urinary tract in acute infection can be obtained by ultrasonography without radiation,[15,16] followed by CT scan in patients for whom ultrasonography is not conclusive or when urological complications or life-threatening conditions such as emphysematous pyelonephritis are suspected.[17] There is now a general consensus that ultrasonography is the primary choice of imaging in most cases of suspected upper UTI due to its lack of harmful radiation, easy accessibility, and low cost, and that a CT scan should be considered as second-line imaging. CT scan with contrast is superior to ultrasonography in differentiating the various forms of renal inflammation and complications, e.g. pyonephrosis and renal abscess. It has also replaced the traditional intravenous urography, as it is possible to scan in the late excretory phase to visualize the collecting system and any obstruction such as stenosis or stones. CT scan is superior to ultrasonography in detecting parenchymal changes caused by acute pyelonephritis, the presence of which confirms the diagnosis. This will, however, seldom lead to changes

in the treatment of the patient, and therefore the examination is not a routine procedure in all patients. What must be detected are complications of upper UTIs such as obstruction with potential risk of kidney function loss and abscess formation in the renal parenchyma or peri-renal space requiring surgical intervention.

Our study included a group of patients with bacteremia originating from a urinary tract focus. The large number of patients consecutively recruited was possible through the use of the North Jutland Bacteremia Research Database at our institution.[18] The strength of this study relies on the registration in the database of patients with urosepsis, considered the most serious UTIs, with a high probability of urinary tract abnormalities. The participating patients represented an unselected cohort, thus reflecting the daily practice of emergency medicine.

The study design has limitations with regard to the level of information that can be obtained in a retrospective study. Firstly, clinically important symptoms and signs such as flank pain and fever, including fever duration, were not consistently noted, for instance when patients were admitted under a completely different diagnosis like chest pain. When there was no information available regarding such a symptom or a pre-existing comorbidity, it was classified as not present. This could have resulted in misclassification bias. Secondly, patients were assigned to the group of 'scanned patients' if during the admission in question they were referred for radiological imaging. Some patients were in hospital for long periods because of complicated illnesses and were scanned one or more times during their stay, and some were scanned after admission, which makes it difficult to define which patients to scan in the acute phase of the urosepsis.

Thirdly, in chronic renal disease, diagnostic imaging of the kidneys will normally reveal small kidneys, diminished parenchyma, or renal scars, with some exceptions (e.g., polycystic kidney). The question is, however, whether the association between kidney disease and major abnormalities actually reflects a high probability of urological complications or whether it reflects that these patients have a loss of kidney function as a direct consequence of their pre-existing major abnormality. Nevertheless, this uncertainty does not change the recommendation that it is advisable to perform imaging of the urinary tract during urosepsis in patients with existing renal disease. Finally, the moderate sample size is a limitation because few patients actually had pre-existing structural urinary tract abnormalities and very few presented findings needing urgent urological intervention. The sample size of our cohort was not powered to show an association between more rarely occurring predisposing conditions and radiologic abnormalities.

In conclusion, a significant fraction (32%) of the subset of patients scanned in this study had clinically important radiological findings, indicating that an abnormality of the kidney or the urinary tract that could predispose to renal infection is quite common in medical patients with urosepsis. Moreover, at 1-year follow-up an additional number of patients not originally scanned had a clinical indication for imaging of the urinary tract, including cases with detectable abnormalities. We recommend that imaging of the urinary tract be considered in all adult patients with an acute upper UTI and associated bacteremia. A positive history of diabetes with complications, renal disease, urolithiasis, or known structural abnormality may be particularly helpful in clinical decision-making in this group of patients.

Acknowledgement

We gratefully thank Edwin Stanton Spencer, MD, DMSc for his linguistic revision.

Ethical approval: The study was approved by the Danish Data Protection Agency.

Conflict of interest: The authors declare no conflicts of interest. The study did not receive external funding.

References

1. Johansen TE. The role of imaging in urinary tract infections. *World J Urol* 2004;**22**:392–8.
2. Browne RF, Zwirewich C, Torreggiani WC. Imaging of urinary tract infection in the adult. *Eur Radiol* 2004;**14**:E168–83.
3. Kawashima A, LeRoy AJ. Radiologic evaluation of patients with renal infections. *Infect Dis Clin N Am* 2003;**17**:433–56.
4. June CH, Browning MD, Smith P, Wenzel DJ, Pyatt RS, Checchio LM, et al. Ultrasonography and computed tomography in severe urinary tract infection. *Arch Intern Med* 1985;**145**:841–5.
5. James JM, Testa HJ. Imaging techniques in the diagnosis of urinary tract infection. *Curr Opin Nephrol Hypertens* 1994;**3**:660–4.
6. Kaplan DM, Rosenfield AT, Smith RC. Advances in the imaging of renal infection. Helical CT and modern coordinated imaging. *Infect Dis Clin North Am* 1997;**11**: 681–705.
7. Kawashima A, Sandler CM, Goldman SM. Imaging in acute renal infection. *BJU Int* 2000;**86**(Suppl 1):70–9.
8. Wang IK, Chang FR, Yang BY, Lin CL, Huang CC. The use of ultrasonography in evaluating adults with febrile urinary tract infection. *Ren Fail* 2003;**25**:981–7.
9. van Nieuwkoop C, Hoppe BP, Bonten TN, Wout TW, Aarts NJ, Mertens BJ, et al. Predicting the need for radiologic imaging in adults with febrile urinary tract infection. *Clin Infect Dis* 2010;**51**:1266–72.
10. Freundlich M, Thomsen RW, Pedersen L, West H, Schønheyder HC. Aminoglycoside treatment and mortality after bacteraemia in patients given appropriate empirical therapy: a Danish hospital-based cohort study. *J Antimicrob Chemother* 2007;**60**:1115–23.
11. Larsen IK, Pedersen G, Schønheyder HC. Bacteraemia with an unknown focus: is the focus de facto unknown or merely unreported? A one-year hospital-based cohort study. *APMIS* 2011;**119**:275–9.
12. Papanicolaou N, Pfister RC. Acute renal infections. *Radiol Clin North Am* 1996;**34**:965–95.
13. Ulleryd P, Zackrisson B, Aus G, Bergdahl S, Hugosson J, Sandberg T. Selective urological evaluation in men with febrile urinary tract infection. *BJU Int* 2001;**88**:15–20.
14. Stunell H, Bucjley O, Feeney J, Geoghegan T, Browne RF, Torreggiani WC. Imaging of acute pyelonephritis in the adult. *Eur Radiol* 2007;**17**:1820–8.
15. Spencer J, Lindsell D, Mastorakou I. Ultrasonography compared with intravenous urography in investigation of urinary tract infection in adults. *Br Med J* 1990;**301**:221–4.
16. Andrews SJ, Brooks PT, Hanbury DC, King CM, Prendergast CM, Boustead GB, et al. Ultrasonography and abdominal radiography versus intravenous urography in investigation of urinary tract infection in men: prospective incident cohort study. *Br Med J* 2002;**324**:1–6.
17. Joseph RC, Amendola MA, Artze ME, Casillas J, Jafri SZ, Dickson PR, et al. Genitourinary tract gas: imaging evaluation. *Radiographics* 1996;**16**:295–308.
18. Søgaard M, Schønheyder HC. Existing sources for clinical epidemiology: the North Denmark Bacteraemia Database. *Clin Epidemiol* 2010;**2**:171–8.